Site Productivity
Can it Go Up in Smoke?

by Richard Bigley and Sabra Hull

When the smoke clears, the first assessments of wildfire damage are in terms of acres. Later, the other costs are inventoried; the number of engine companies and firefighters recruited, miles of fire line constructed and perhaps even meals consumed. All those statistics are important, but what is left for the forester to manage? How do forest fires influence the site's ability to grow timber and support other forest values? As we try to increase wood production on a limited land base, various impacts on long-term site productivity are of increasing concern. The substantial accumulations of mineral nutrients and organic matter in forests are literally the capital on which the forest industry is based. If you think otherwise, talk to foresters in the Yacolt District in Southwest region about what frequent and intense fires can do to the land's capacity to produce wood.

The vegetation on a given site type has evolved with fire at particular intensities and frequency (see Table 1). Some site types have evolved with short fire return intervals, and may depend on fire to maintain their character and productivity. For example, consider ponderosa pine communities on the east side. Fire suppression on these sites can result in the accumulation of thick forest floors, brushy understories, and promotion of less fire-resistant tree species. These changes not only pose regeneration problems, but also make the sites more susceptible to severe wildfires.

Table 1. Fire return intervals for Washington by stand type (Modified from Agee, 1993).

Forest type	Fire cycle (Years)
Cedar/spruce/hemlock	937
Subalpine	500
Douglas-fir	217
Lodgepole pine	110
Woodland	25
Ponderosa pine	15

In some cases, nearly 40% of soil nitrogen can be lost by fire.

Fire can affect forest productivity by influencing many soil characteristics, including nutrients, physical structure, and the ability of plants to reestablish. The duration of these effects varies greatly, depending on the severity and duration of the fire, and the biological and geological character of the site. Some of our most productive sites may be unscathed by fire, whereas the productivity of poor sites would be reduced for decades. The many apparent contradictions in the literature concerning fire effects likely result from inappropriate comparisons of different burn severities and ecosystem types, seasonality and moisture conditions.

Which sites are most at risk of productivity loss?

The impact of fire on the productivity of a particular site depends in part on where nutrients are stored before the fire. On very dry, wet, or cold sites, the forest floor acts as a sort of nutrient bank, with the nutrients locked up in the litter and perched above the mineral soil. Such sites have much to lose when a hot fire burns off the organic accumulations. On more mesic sites, rapid decomposition and mixing of organic materials with the mineral soil results in relatively thin forest floors. On these sites, the organic component of the soil is in a sense armored by the mineral soil, and is

Productivity losses from fire may not be evident for 15 years.

consequently much less vulnerable to the effects of fires.

To predict a site's susceptibility to nutrient loss due to fire, scuff aside the forest floor and look at the extent of mixing of organic matter and mineral soil. A thin organic layer above mineral soil that is full of earthworms and well mixed with organic matter is likely to fare well in a fire. If the forest floor is thick, laced with fungal mycelia, and the horizon between the organic matter and mineral soil is sharp, the site is likely more vulnerable to losses in productivity due to fire.

Short-term impacts of fire

Initially, fire can have a profound effect on the physical characteristics of soils and the site's ability to regrow rapidly. Burning can increase overland water flow and soil erosion through several different processes, including the removal of vegetation and forest floor; reduction in soil porosity; formation of a hydrophobic layer in the soil (especially in dry climates); and breakdown of soil structure. Removal of the forest floor can also result in wider temperature fluctuations at the soil surface and can contribute to dry soils that impede initial plant growth.

Fire usually increases the short-term availability of many nutrients in the soil by changing the chemical form of some nutrients, and changing soil processes. For instance, decreased pH results in faster breakdown of organic material by microbes. For the first several years following fire (or logging, for that matter) nutrient demanding species such as fireweed and blackberry increase dramatically, even on poor sites. This is the result of a pulse of nutrients, known as the Assart Effect (after an old English word meaning to clear forest land to make it arable), that may allow the forest to reestablish and grow well for the first 10 years or so after the fire. However, once the nutrients made available by decomposition of dead fine roots, and litter are depleted, the growth of trees may suffer. In some cases, nutrient availability may actually decline below pre-fire or preharvest levels. Nutritional problems due to fire may not show up for 15 years after the fire.

Long-term impacts of fire

Wildfire, like harvesting, inevitably removes nutrients from forests and has the potential to influence long-term site productivity. Many of the nutrients from the combustion of organic matter take the form of chemical oxides after the fire, and are subject to loss as fly ash. Each ton of organic matter consumed produces about 3 pounds of ash. Ash not sent adrift by fire-induced convection currents can be washed or blown from the site. The ash usually contains 12 percent calcium, 2 percent magnesium, 10 percent potassium, and represents a valuable site resource. Two years following a fire at Entiat (north central Washington,) about half of the less volatile nutrients in the top 15 inches of soil were transformed into a soluble form and were readily leached from the site. (See Table 2). In addition to the nutrient losses shown above, stream flow increased 15%, carrying with it increased concentrations of nitrogen. However, stream water losses were insignificant compared with the losses that occurred during the fire itself.

Table 2. Nutrient losses after 1970 wildfire at the Entiat Experimental Forest (after Grier, 1975)

	Nitrogen	Calcium	Magnesium	Potassium	Sodium
Nutrient content of unburned soil (pounds per acre)	2061	626	192	787	754
Estimated total nutrient losses from volatilization and ash convection (pounds per acre)	809	67	29	275	623
Conservative estimate of total ecosystem nutrient loss as a result of the fire	39%	11%	15%	35%	83%

During combustion, both nitrogen and sulfur are converted to gas and are lost from the soil in large amounts. On most forests in the Northwest, nitrogen is recognized as the most limiting nutrient. The common natural sources of nitrogen in the soil are from precipitation (about 5 lbs/acre/year) and fixation of atmospheric nitrogen by microbes. Volatilized nitrogen is not easily replaced. It is possible that sulfur deficiencies may be important to the long-term maintenance of forest productivity, because sulfur is not fixed biologically. Several studies have found a favorable response to nitrogen and sulfur fertilization on some sites.

In summary, the effects of fire depend greatly on the severity and frequency of the fire, and on the site type. Forest managers should be cognizant of the forest floor type and fire history when they develop fire management plans for a given site. In areas where fire frequency is high, and/or burning intensity is high, depletion of both nitrogen and sulfur can be a problem. Fertilization and careful control of wood utilization during harvest may help to mitigate fire effects on such sites.

Richard Bigley

Sabra Hull